Clinical Studies of Selective Cine Coronary Arteriography and Surgical Revascularization of Ischemic Myocardium Part 2 Surgical Revascularization of Ischemic Myocardium

AUTHOR(S):

SHIRAI, OSAMU

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Clinical Studies of Selective Cine Coronary Arteriography and Surgical Revascularization of Ischemic Myocardium

BY

OSAMU SHIRAI

The 2nd Surgical Division, Kyoto University Medical School
(Director: Prof. Dr. CHUJI KIMURA)

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Part 2
Surgical Revascularization of Ischemic Myocardium

I. Introduction

Although many operative procedures have recently been proposed for the treatment of ischemic heart disease, only few of these procedures deserved extensive clinical application and there are still disagreements as to the effect of surgical intervention.

Among many operative procedures thus proposed, the implantation of internal mammary artery into myocardium originally initiated by VINEBERG[1] is now being accepted by increasing number of chest surgeons as one of effective treatments for ischemic heart disease.

This study was undertaken to evaluate the clinical application of the implantation of internal mammary artery into myocardium.

II. Review on the development of surgical treatment of ischmic heart disease

Many investigators have suggested different surgical procedures for the relief of ischemic heart disease.

In 1920, for the purpose of blocking of the pain conducting pathway, cervicothoracic ganglionectomy was proposed by JENNESCO[2]. By this procedure, LINDGREN[3] found definite relief of pain on the operative side in 64% of the patients.

In 1933, the idea of total thyroidectomy was introduced to reduce the metabolic demands of the body for the treatment of angina pectoris. BLUMGART[4] reported that 47% of 95 patients received excellent relief of symptoms from thyroidectomy.

These procedures, however, were soon abandoned by the reason why they did not seem to effect coronary blood flow significantly, even though many patients had symptomatic improvement.

Since then, attempts have been made to increase the net arterial flow to myocardium, either by the technique of coronary endarterectomy or by trying to supply the heart with arterial blood from systemic arteries. BECK[5] produced pericardial adhaesions by abrasion of heart with scraping or by adding irritants such as asbestos or talc inside the pericardium. This procedure was used to open the anastomosis between the pericardial systemic arteries and the coronary endarteries. Ligature of the internal mammary arteries was performed by FIESHI[6] in 1942 in order to produce proximal hypertension and increase collateral flow through the pericardiophrenic artery to the pericardium and secondarily to the heart.

In spite of surgical procedures above described, either implantation of internal mammary artery into ischemic myocardium or direct coronary revascularization with bypass graft of saphenous vein is currently receiving more attention of cardiac surgeons.

In 1946, VINEBERG[1] devised a technique whereby a bleeding systemic artery was implanted into the myocardium for the purpose of increasing blood flow to the heart. In 1952, he[7] firstly performed implantation of internal mammary artery into the left ventricular myocardium of the patients.

This ingenious idea that a bleeding artery could be implanted within myocardium without causing a hematoma and without producing intravascular clotting was generally disagreed by the contemporary cardiac surgeons. In 1958, SONES selectively opacified the patency of internal mammary artery that had been implanted several years previously by VINEBERG himself. That arteriography clearly showed that implanted artery had formed capillary anastomosis with proximally obstructed anterior descending artery. Objective evidence of VINEBERG's operation apparently stimulated enthusiasm of cardiac surgeon for potency of the surgical treatment of ischemic heart disease.

Since then, surgeon searched another neighboring artery which might be available for revascularizing the heart and could reach to the heart. The splenic artery[8] and intercostal artery[9] were thought to be available, and gastroepiploic artery[10] was more accessible to the posterior aspect of the heart.

Even after the trial of above mentioned variations, the internal mammary artery has been proved to be most potent source of blood supply for indirect coronary revascularization.

This procedure, however, did not seem to immediately supply the ischemic myocardium with extrinsic arterial blood and four to six months were necessary for collateral anastomotic vessels to develop. Early clinical experience of peripheral vascular surgery has stimulated direct coronary revascularization including endarterectomy[11], patch graft endarterectomy[12], segmental interposition of saphenous vein[14], internal mammary-coronary artery bypass[15], and aortocoronary bypass by saphenous vein[13].

In 1968, the saphenous vein for bypass grafting in the coronary circulation was extensively used by FAVALORO[13] at the Cleveland Clinic. Since then bypass graft by saphenous vein has a tendency to be employed as effective treatment for ischemic heart disease by many investigators.

III. Operative technique of internal mammary artery implantation

All patients were digitalized and were given coronary vasodilators as Nitrol preoperatively.

Blood pressure and electrocardiogram were carefully monitored to predict undesirable hypotension or refractory arrhythmia resulting from the manipulation on heart throughout operation. Mixture of Halothane, nitrous oxide, and oxygen were used for anaesthesia.

The patient was placed on the table in the right lateral position, The skin incision extended from the midline anteriorly to the posterior axillary line. The left pleural space is entered in the fifth intercostal space.

Both the lung and pericardial fat pad are retracted posteriorly to expose the left internal mammary bundle and the internal mammary artery is made visible down to the third or fourth intercostal space. Mobilization of the internal mammary artery may be a tedious procedure and initial mobilization of the artery begins at the third or fourth intercostal space. The internal mammary artery is freed from overlying pleura, fascia, muscle to the first intercostal space. The intercostal branches isolated are ligated with fine silk and are devided.

Dissection of the artery at the fifth and sixth intercostal space is most carefully undertaken. All branches at that level are considered as a potential source of the revascularization. At sixth intercostal space, the internal mammary artery usually joins the superior epigastric artery.

The mobilized internal mammary artery is left in continuity and the vessel is protected by gause previously soaked in the solution of Papaverin. Papaverin affords effective relief of vasospasmus resulting from the extensive dissection.

Pericardial fat pad is dissected away from the underlying pericardium. After injection of 2% Xylocain into pericardial sac, the pericardium was widely opened with T or Y shaped incision.

Careful examination is made by palpation of the right, anterior descending, and left circumflex artery. The surfaces of both ventricles are inspected for the presence of myocardial infarction.

When the freeing of the internal mammary artery from chest wall is completed, the superior epigastric artery is ligated as distally as possible. The internal mammary artery was pumped from distal end with physiological saline solution containing Heparin. The preserved side branches are cut as close to the parent vessel as possible and one or two additional incisions in arterial wall are added to create the side holes. Typical implant has three or four actively bleeding branches.

The location of the tunnel is determined by the finding of coronary arteriography. The length of the myocardial tunnel ranges from 4 to 5cm. The axis and length of tunnel are fixed by two stab wounds on the ventricular myocardium. The tip of specially designed clamp is inserted into a distal stab wound and clamp is guided to the proximal stab wound in the depth of two thirds of whole myocardium. The artery is pulled through so that all of bleeding branches are enclosed within the

whole length of the tunnel and it is fixed in position by the later suture which was placed in the myocardium. Twisting of the artery should be avoided by careful inspection (Figures 1 and 2).

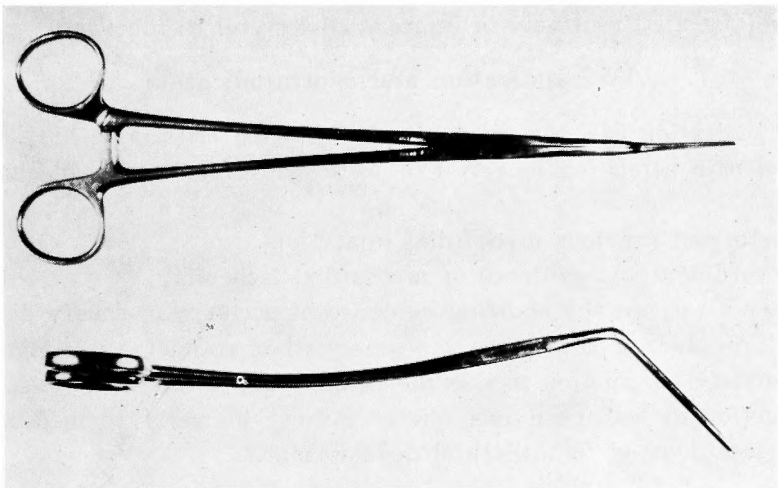
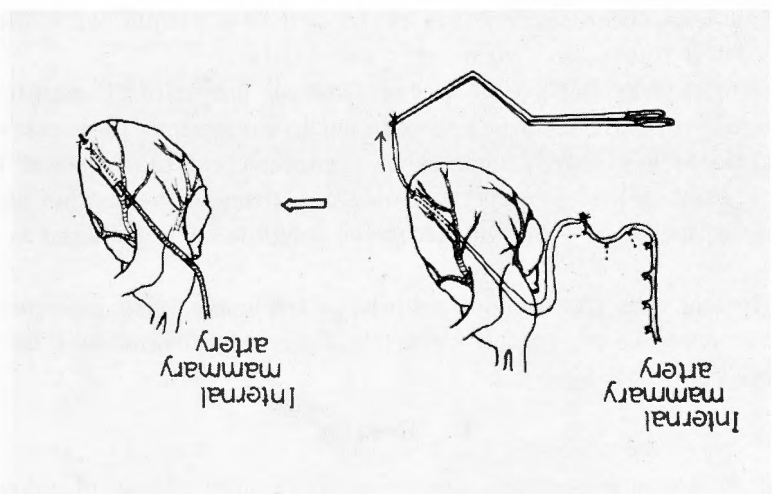


Fig. 1 Specially designed tunnel clamp.

Implantation of internal mammary artery



The internal mammary artery has been implanted into a myocardial tunnel

Fig. 2

Any bleeding from the proximal wound of the tunnel is controlled by light pressure over a gause sponge.

The lung is expanded to make certain that the lingula does not encroach upon the internal mammary artery. The pericardium itself is not closed to prevent the constriction of implanted artery.

A thoracotomy tube is inserted and then the chest is closed in routine fashion.

Maintenance of the adequate blood pressure is the most important feature in the postoperative care. Nitrol is continuously administrated as long as 6 months postoperatively and digitalis is discontinued as it is not indicated. Pyridoxal phosphate was also administrated routinely to improve cholesterol metabolism.

IV. Indication and contraindication

Surgical indication is determined by the following criteria.

1) Anginal pain persisting longer than one year in spite of adequate medical therapy.
2) The history of previous myocardial infarction.
3) Electrocardiographic evidence of myocardial ischemia.
4) Coronary arteriography showing evidence of occlusive coronary disease.

Surgical procedure should be effective only when coronary arteriography shows sufficient coronary obstruction to rise the demand for collateral. SEWELL[17] observed that a obstruction to less than one quater normal diameter seemed necessary to provide adequate demand for collateral development.

In the presence of recent myocardial infarction, VINEBERG insists that any surgical procedure must be delayed for a period of six months. There seems to be two reasons for postponing several months; 1) to enable the heart to scar solidly the area of infarction and 2) to see how the patient does clinically. In this study, surgical procedure has been successfully performed in a patient who had an attack of acute myocardial infarction two months previously.

If the patient is over the age of 65 years old, or has clinical manifestations of refractory congestive heart failure, uncontrolled hypertension, frequent episodes of atrial tachycardia or ventricular tachycardia, manifest valvular disease to indicate surgery, severe emphysema, or associated incurable diseases, he can not be considered as a candidate of operation. Angina decubitus itself is not considered as contraindication.

SEWELL[19] insists that the patients who have triple coronary diseases and have an end-diastolic pressure in the left ventricle above 14mmHg should be considered as angiographic contraindication.

V. Results

A total of 20 patients has been performed revascularization of myocardium in the past three years. They are 15 patients with angina pectoris and five patients with previous myocardial infarction ranging in age from 29 to 63 years. Some of their coronary arteriographies are showed in Figures 3, 4, 5 and 6.

Results of coronary arteriography in operative series are summarized in Table 1. Obstructive disease was found in 59 main coronary arteries. The right coronary artery was involved in 11 patients (55%), the left main in 12 (60%), the anterior descending in 19 (95%), and circumflex in 17 (85%). Single or multiple obstructions exceeding 75% narrowing were recognized in 15 operated patients (Table 2).

The implantation of left internal mammary artery was performed in 18 patients.

Table 1

Cases of Myocardial Revascularization

Case No.	Age Sex	Diseases	Operations	Coronary arteriography RCA	LMCA	ADA	LCA	Results
1	41M	AP	implantation of left IMA	0	1	3	0	excellent
2	44M	MI	implantation of left IMA	3	2	3	3	excellent
3	51M	AP	implantation of left IMA	1	1	2	3	excellent
4	56F	AP	implantation of left IMA	1	1	2	2	excellent
5	53M	AP	implantation of left IMA	1	1	2	3	excellent
6	50M	AP	implantation of left IMA	1	0	1	3	good
7	33M	MI	implantation of left IMA	0	0	0	3	excellent
8	60M	AP	implantation of left IMA	0	1	3	1	good
9	44M	AP	implantation of left IMA	0	1	3	3	good
10	38M	MI	implantation of left IMA	1	1	3	1	excellent
11	35M	MI	implantation of left IMA	3	1	1	3	excellent
12	46M	AP	implantation of left IMA	0	0	3	1	excellent
13	38M	AP	implantation of left IMA	2	0	2	1	excellent
14	54M	AP	implantation of left IMA	0	0	2	0	excellent
15	49M	MI	interposition of saphenous vein implantation of left IMA	3	1	3	1	died after 4 hours postoperatively
16	63M	AP	bypass graft of saphenous vein	3	0	2	1	died after 1 month postoperatively
17	29F	AP	implantation of left IMA	0	0	2	0	*
18	30M	AP	implantation of left IMA	0	0	2	1	*
19	51F	AP	implantation of left IMA	0	1	3	1	*
20	57M	AP	implantation of left IMA	2	1	3	2	*

excellent=working full time without any anginal pain
good=working full time with infrequent anginal pain
*=postoperative follow up is not long enough to evaluate effect of the operation

Table 2

Obstructive Regions of Coronary Branches in 20 Operated Patients

Coronary	Branches	Involved No. of patients more than 25%	more than 50%	more than 75%
ADA		19 (95%)	17 (85%)	9 (45%)
LCA		17 (85%)	9 (45%)	7 (35%)
LMCA		12 (60%)	1 (5%)	0 (0%)
RCA		11 (55%)	6 (30%)	4 (20%)

There have not been apparent postoperative complication in this procedure except two patients with hemothorax. Atelectasis due to hemothorax was restored by several thoracentese.

In postoperative courses of 14 patients with VINEBER's operation, 5 patients had not attack of anginal pain postoperatively and were classified as satisfactory. Five patients began to suffer from slight anginal pain on seventh to tenth postoperative

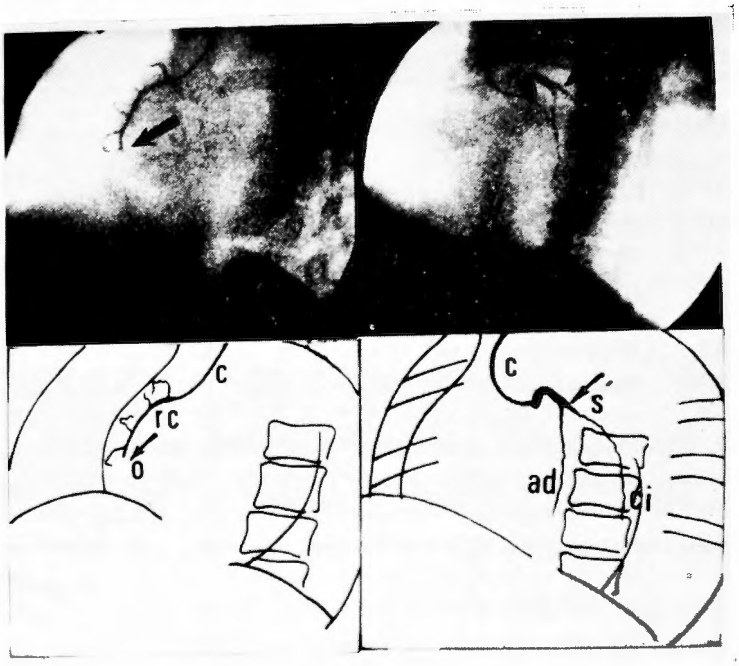


Fig. 3 Single frame from the coronary arteriography of a patient with previous myocardial infarction. The arrows mark complete obstruction in right coronary and severe obstruction in anterior descending and and left circumflex.

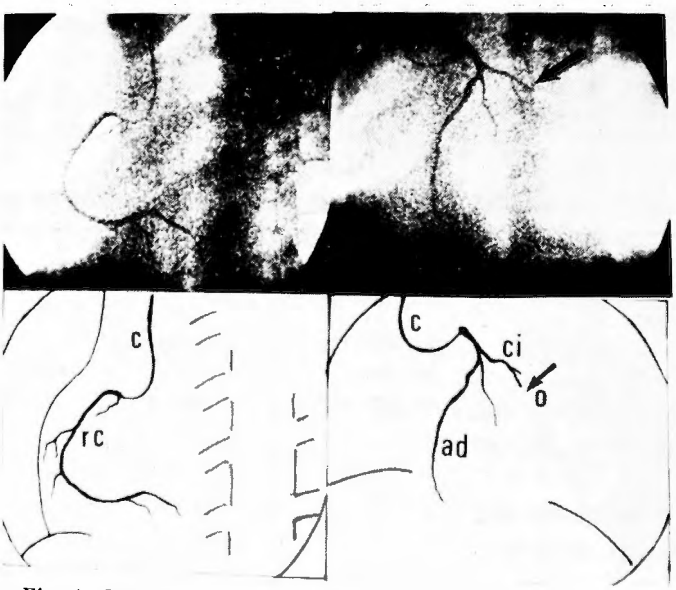


Fig. 4 Single frame from the coronary arteriography of a patient with previous myocardial infarction. The arrow marks complete obstruction in distal part of left circumflex.

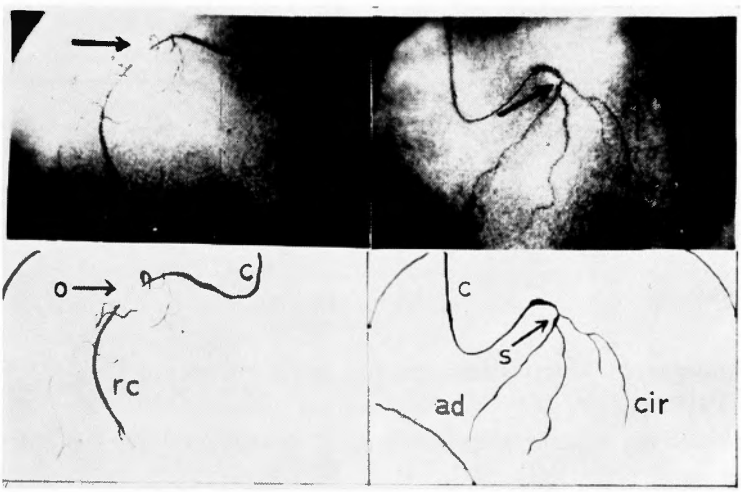


Fig. 5 Single frame from the coronary arteriography of a patient with typical angina. The arrows mark complete obstruction in right coronary and severe obstruction in origin of anterior descending.

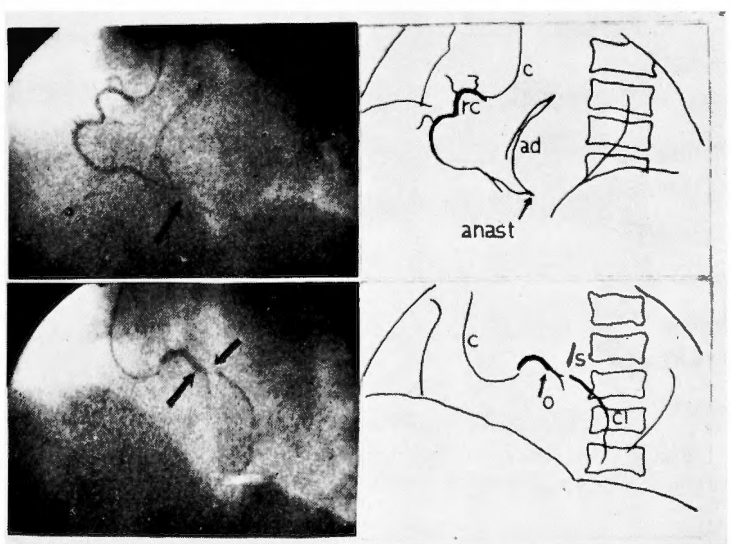


Fig. 6 Single frame from coronary arteriography of a patient with typical angina. The arrows mark complete obstruction in origin of anterior descending and severe obstruction of left circumflex, and anastomosis between distal part of right coronary and its of anterior descending.

day and become asymptomatic within one to six months. Residual 3 patients still continue to suffer from slight anginal pain over the period of 6 months after the operation (Table 3).

However, all of them returned to former occupation with almost full activity at the present time.

Table 3

Disappearance of anginal attack after Vineberg's operation

Anginal attack	Myocardial infarction	Angina pectoris	total
no attack	3	3	6
disappeared within 1 month	0	2	2
disappeared within 2 to 6 months	1	2	3
continue more than 6 months	0	3	3
total	4	10	14

Their postoperative electrocardiograms were improved in only four patients, and unaltered in 10 patients.

Figure 7 shows significant improvement of postoperative electrocardiogram.

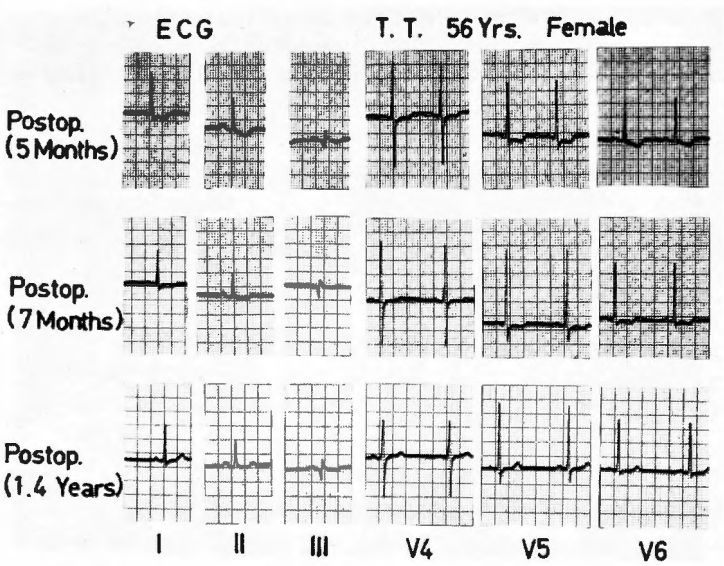


Fig. 7 Postoperative improvement in electrocardiogram of a patient with typical angina.

The definite correlation between postoperative electrocardiogram and clinical improvement was not concluded.

Internal mammary arteriography to opacify the patency of vessels and collateral development has been performed in 5 patients. Internal mammary artery were opacified in all 5 patients. Two vessels were proved to have significant collateral communications with coronary artery and coronary veins were also opacified. Other 3 vessels had less significant collateral communications. Figure 8 shows patency of implanted internal mammary artery and significant collateral communications with own coronary artery.

Direct saphenous vein grafting of coronary artery were performed in 2 patients in this study. A patient was performed interposition of right coronary artery with

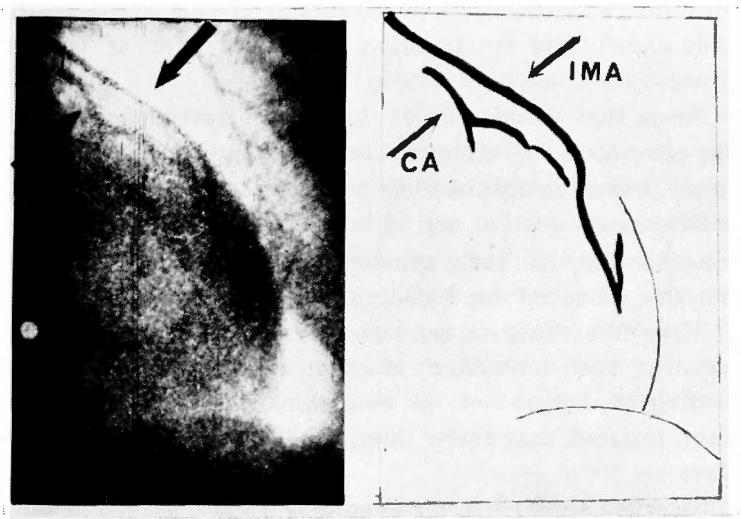


Fig. 8 Single frame from internal mammary arteriography of the patient demonstrated in Figure 6. The arrows mark patent internal mammary artery and own coronary artery.

saphenous vein and implantation of left internal mammary artery into left ventricular myocardium. Another underwent aortocoronary bypass graft of right coronary artery with saphenous vein. Unfortunately the former died from refractory ventricular fibrillation four hours postoperatively and the latter died from an attack of acute myocardial infarction 31 days ofter operation.

Table 4

Operative Mortality Following Internal Mammary Implantation in Different Clinical Studies

Investigator	Operative Method	Cases of Operation	Mortality	Percent
Vineberg	Standard Operation	140	7	5.0%
Vineberg	Combined Operation	62	6	9.7%
Favaloro	Single Implantation	614	33	5.4%
Favaloro	Double Implantation	150	14	9.3%
Sewell	Pedicle Operation	240	15	6.3%

VI. Discussion

Anatomical structure of the ventricular myocardium have the extensive vascular network provided by intramyocardial sinusoids. Because of characteristic structure of the myocardium, an implanted internal mammary artery fails to form hematoma and remains patent for an indefinite period of time.

VINEBERG[20),21)] believes that blood shifts from internal mammary artery to myocardial sinusoids after implantation, and sinusoids can provide runoff from internal mammary artery until collateral channels to coronary arteries develop. However,

arteriographic finding and observation by corrosion cast at postmorten, suggested that the sinusoids usually did not function in this way for at least several hours after implantation.

SEWELL[19] believes that thrombosis of the blind distal end of internal mammary artery is usually prevented by reflux of blood moving back and forth with heart beat. Nevertheless, exact mechanism of providing patency of internal mammary artery at immediate postoperative period is still unknown.

TRAPP[22] demonstrated that early anastomosis occurred in process of three phases; namely 1) hematoma produced by bleeding branches of the implanted artery, 2) capillary or capillary-like channels arise from the hematoma and anastomose with the naturally existing vascular system of heart, and 3) naturally occurring vessels incidentally residing in the area of the hematoma eventually connect directly with hematoma. Trapp insisted that these three phases were apparent as early as six postoperative day.

VINEBERG[20] observed that the artery could be seen to branch at the end of twelve days, and these branches grow into wellformed arterioles which joined up with arterioles lying in the left ventricular myocardium at the end of three to four weeks.

His statement may correspond with the fact that 5 patients in this study began to suffer from slight anginal pain on seventh to tenth postoperative day and became asymptomatic within one to six months.

It is well known that the greater the differential pressure between implanted internal mammary artery and coronary artery, the sooner is the progress of the artery branching. VINEBERG[20] reported that the anastomotic rate averaged 71% in ischemic hearts in comparison with 46% in non-ischemic hearts.

GRIOLLOS[23] observed that an average flow of 70 ml/min equivalent to 25% of normal coronary blood flow was directed into the ischemic canine heart from bilateral mammary arteries, however an average flow shifted into non-ischemic canine heart was only 18 ml/min.

PROVAN[24] measured blood flow of internal mammary artery by means of an electromagnetic flow meter after implantation in dogs. In the presence of demand for increasing coronary flow, initial increase of flow in the implant took place 6 weeks after implantation and that flow continued to increase for up to 6 months. In his experiments, the pattern of phasic flow of internal mammary artery resembled that of coronary artery, not that of systemic artery.

In original VINEBERG's procedure, the left internal mammary artery was detached from the chest wall from the fourth to sixth intercostal space, and was bured into tunnel in the left ventricular wall. One to two intercostal vessels are left open to bleed into the myocardial tunnel.

One of modifications was made by EFFLER[25] who used a longer myocardial tunnel. EFFLER's myocardial tunnel was 4 to 5 cm long, whereas the tunnel of original VINEBERG's procedure was 2.5 to 4 cm long.

Another modification made by SEWELL[17)26)27)28], was named pedicle operation;the inclusion of internal mammary vein and surrounding soft tissues along with internal

mammary artery to diminish injury of artery and to avoid undesired torsion of the enclosed vessel.

SEWELL[27),28)] used a knife to make his myocardial tunnel, whereas VINEBERG made the tunnel by spearing a clamp.

Site of coronary artery disease, however, is often multiple and myocardial ischemia may be diffuse. For these reasons, efforts were made to develop techniques which would achieve more wide revascularization of the lateral and posterior part of the myocardium. VINEBERG[18),29),30),31)] performed the combined procedure consisting of internal mammary artery implantation, epicardiectomy and free omental graft. FAVALORO[32,33)] performed double internal mammary implantation by midline incision extending from the tip of the sternum to umbilicus. PEARSE[34)] proposed triple operation; namely, implantation of bilateral internal mammary arteries and gastroepiploic artery.

In FAVALORO's[33)] clinical reports, atrial arrhythmia and acute myocardial infarction were the most common complications. These atrial fibrillations usually occurred in the first 48 hours and responsed readily to rapid digitalization. Myocardial infarction were recuperated with usual medical treatment and with bed rest for approximately 3 weeks.

Operative mortality by different investigators are listed in Table. 4, ranging from 5 to 10%.

In this study, there has not been apparent postoperative complication except two cases with hemothorax.

Criteria for postoperative evaluation of VINEBERG's procedure are based on subjective and objective evidences. These include 1) the disappearance or diminution of anginal pain, 2) reduction or cessation of coronary vasodilator drugs, 3) disappearance of heart failure, 4) increase in exercise tolerance, 5) return to work at former occupation, and 6) improvement of electrocardiographic change.

FAVALORO[35)] reported that 167 (79.1%) of 211 patients had improved in his follow up study.

Of 14 patients followed up in this study, 11 were excellent and working full time without any anginal pain. Residual 3 patients were good and working full time with infrequent anginal pain.

Internal mammary arteriography is the only method available so far that gives a direct demonstration of the number, size, and location of collateral communications. In arteriographic study of 131 patients with SEWELL's[19)] pedicle operation, 91 patients of them had patent vessels and 85 patients had collateral vessels. In 127 implants of double internal mammary implantation, FERGUSSON[36)] demonstrated 117 patent vessels and 69 collateral vessels. KAY[37)] designed the indirect method to determine flow computed by cine angiographic technique. In his method, the computed flows ranged 48 to 104cc/min. from both internal mammary artery. BJÖRK[38)], however, showed patent vessels in only 22 of 48 patients and insisted that results of VINEBERG's procedure did not significantly differ from BECK's procedure.

In this study, internal mammary artery were opacified in all 5 patients who were examined. Two vessels were proved to have remarkable collateral commu-

nications with coronary artery and other 3 vessels were proved less significant collateral communications.

The excellent results of direct coronary revascularizations such as interposition of saphenous vein[14], bypass graft of saphenous vein[23], and internal mammary-coronary artery anastomosis[15] were reported by many investigators. Furthermore, combined procedure of direct revascularization and implantation of internal mammary artery[16] is being adopted by increasing number of investigators.

The greatest advantage of direct revascularization is that this procedure immediately supplys the ischemic myocardium with sufficient amount of arterial blood. But real benefit of direct revascularization will not be rationally appreciated until follow up study for longer period is permitted.

VII. Summary

A total of 18 patients was performed implantation of left internal mammary artery into left ventricular myocardium during past 3 years.

There was not severe complication in VINEBERG's procedure.

In follow up study of 14 operated patients, 11 patients are classified as excellent and are working full time without anginal pain. Other 3 patients are good and are working full time with infrequent anginal pain.

Reflecting on postoperative courses of operated patients, it was presumable that collateral branches communicating with coronary artery system might take one to six months to develop.

Postoperative internal mammary arteriography in 5 patients proved various degree of collateral communications with coronary artery.

It is conclusive that VINEBERG's procedure can surely afford one of effective treatments for ischemic heart disease.

Acknowledgement

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和文抄録

選択的冠動脈造影法及び冠動脈血行再建術の臨床的研究

京都大学医学部外科学教室第2講座（指導：木村忠司教授）

白　井　　治

1. 選択的冠動脈造影法

近年虚血性心疾患の外科的治療法の発達と共に，心筋虚血部位及び冠動脈病変の程度を判定する為に冠動脈に直接カテーテルを挿入し選択的に造影する方法が考案され注目されつゝある．著者は3年前本邦に於いてなお未発達である選択的冠動脈造影法の臨床的研究に着手し現在迄狭心症27症例心筋硬塞11症例を含む52症例に施行した．当初懸念された心室細動或いは冠動脈損傷の如き重篤な合併症に遭遇する事もなく行い得たことはこの検査法が比較的安全なものであることを証明している．

装置は Siemens 透視装置及び Arriflex 35㎜ シネカメラを用いた．局所麻酔下に右上腕動脈より Sones のカテーテルを挿入した後患者を第2斜位にし，透視下に冠動脈口に達せしめる．操作に熟達すれば挿入は容易である．造影剤は80%アンギオコンレイ或いは80%コンラキシンHを使用し手押しにて1回量7～10cc を注入した．左右冠動脈への造影剤注入時には心電図に独特の QRS 及びT波の変化を認めた．即ち右冠動脈注入時には右軸偏位及びT波の逆転を，左冠動脈注入時には左軸偏位及びT波の上昇を認めた．

虚血性心疾患35症例より次の如き冠動脈造影所見を認めた．

1) 冠動脈病変は多くの場合多発性で1ケ所のみに限局することは稀である．

2) 冠動脈病変部位は左前下行枝に最も多く左回旋枝，左冠動脈主幹の順序で右冠動脈は最も少ない．

3) 心電図により推定された硬塞部位と冠動脈造影所見は必ずしも一致しない．

著者は本研究に於いて，選択的冠動脈造影法の安全性を確認すると共に，虚血性心疾患の部位及び程度を判定する為に非常に有効な方法である事を証明しえた．

2. 冠動脈血行再建術

Vineberg により創始された内胸動脈心筋内移植術は術後の内胸動脈冠動脈間吻合のX線的確認により，その有効性が証明され虚血性心疾患の外科的治療法として注目されつゝある．

著者は過去3年間選択的冠動脈造影所見より冠動脈狭窄及び閉塞を認めた18症例に左内胸動脈心筋内移植術を施行した．

手術々式は第5肋間にて開胸後左内胸動脈を第1肋間より第6肋間迄丁寧に遊離し特殊鉗子を用いて内胸動脈末梢端5㎝を左室心筋内に埋没する．埋没すべき末梢端には肋間枝及び補助孔を含めて平均4個の側孔を作製し，それらの側孔からは絶えず動脈血が噴出したまゝである．埋没部での血腫形成は認められない．

14症例の遠隔成績では11症例に狭心痛発作が全く消失し，3症例に今なお軽度の狭心痛発作を認めているが全て従来の職業に復帰している．又狭心痛発作が消失した11症例中5症例では術後1～6ケ月間軽度の狭心痛発作が持続した後消失しており，これは副血行路の形成される期間であろうと推測している．

術後内胸動脈造影を5症例に行い，全ての症例に内胸動脈の開存を認めている．2症例では冠動脈との吻合が著明であり，他の3症例は細い吻合枝を認めている．

以上の所見より，著者は虚血性心疾患の外科的治療法として内胸動脈心筋内移植術の有効性を証明したものと考える．しかし手術効果の発現が緩徐である点より，この術式の限界性を認めねはならない．